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# Exploring the Deeper Hydrocarbon Potential of Mature Upper Assam Basin, Assam, India

## Abstract:

Exploration of Paleocene-Eocene Formation is limited to the central part of the basin close to Brahmaputra arch. Due to southerly dip of the basin, thickness of the post Eocene sediment increases toward the frontal thrust region. Paleocene Eocene play in this region is expected to be encountered at depths of 5500-6500 m. At the same time, fold and thrust belts are challenging frontiers for hydrocarbon exploration because of complex and uncertain structural geometry. Extensive exploration in the sub-thrust regime remains a potential play at deeper formations. Lack of well data along with poor imaging makes it difficult to decipher correctly the subsurface geometries, especially for the sub-thrust plays. Velocity issues across thrust planes make it difficult to predict target depths leading to greater uncertainties. This area, with working petroleum system is a promising hydrocarbon exploration target but having uncertain trap definition. Exploration of deeper hydrocarbon play in southern part and thrust belt region are yet to be fully explored and efforts toward exploration of these plays will open a vast area for future exploration in Upper Assam Basin.

## Introduction:

Upper Assam Tertiary sedimentary basin is one of the important petroliferous basins in India and has been producing oil and gas for more than a century. It is a composite foreland basin situated in North East of India, developed as a result of crustal loading. It lies between two orogenic belts, viz the ENE-WSW trending Himalayan Fold and Thrust Belt and NE-SW trending Assam-Arakan Fold and Thrust Belt (Figure 1). The Shelf is bounded by the Shield of Mikir Hills towards its west and Mishmi Hills along its northeastern boundary (Figure 2). The Upper Assam Shelf contains around 3500-7000 m thick sediments of mostly Tertiary and Quaternary age. A poly phase deformation history is responsible for the development of the present day structural style and tectonic set-up of the Assam Shelf. The first phase was extensional and occurred during Early Cretaceous; the area represents trans-tensional tectonic regime where most of the major faults formed trend NE-SW direction. These have been dissected by cross faults and resulted in creation of horst and graben structures. The second phase was a major compressional phase and occurred during Early Miocene as a result of which many basement faults were reactivated due to compressional tectonics with development of compressional and inverted structures. The third, compressional phase (Himalayan upliftment) occurred during Plio-Pleistocene and this NW-SE compressional movement had generated the transverse system of faults which has dissected the earlier longitudinal fault system.

Discovery of oil in this basin dates back to the year 1867 near Margherita, Assam, seven years after the world's first discovery of oil in Pennsylvania, USA. The oil was discovered close to the Naga thrust which is the frontal thrust of Assam-Arakan Fold and Thrust belt. Following this, oil was discovered in Digboi and the first commercial production of oil was started in the year 1889. Subsequently, commercial discovery of oil and gas in the foreland part was made in 1950's in Nahorkatiya and Moran. Hydrocarbon discoveries were also made in oil fields like Jorajan, Kathalguri, Nagajan, Hapjan and Shalmari during 1960's to 1980's. These discoveries of oil and gas were in the shallower Tipam (Miocene-Pliocene) and Barail (Upper Eocene-Oligocene) formations in the depth range of 2000-3000 m. These were mostly deposited in fluvial and fluvio-deltaic environments and the reservoirs were thick (in the range of 20-50 m) and having good porosity. These discoveries were large in terms of both area and volume.
The discoveries in deeper Paleocene-Eocene formation were made in the early 1990's and 2000's. These discoveries were small compared to that of Oligocene-Miocene reservoirs. These reservoirs were mostly deposited in shallow marine environment with thickness in the range 2-10 m at the depth

of 3500-5600 m. At present, Paleocene-Eocene reservoirs contribute around 60% of OIL's annual production.

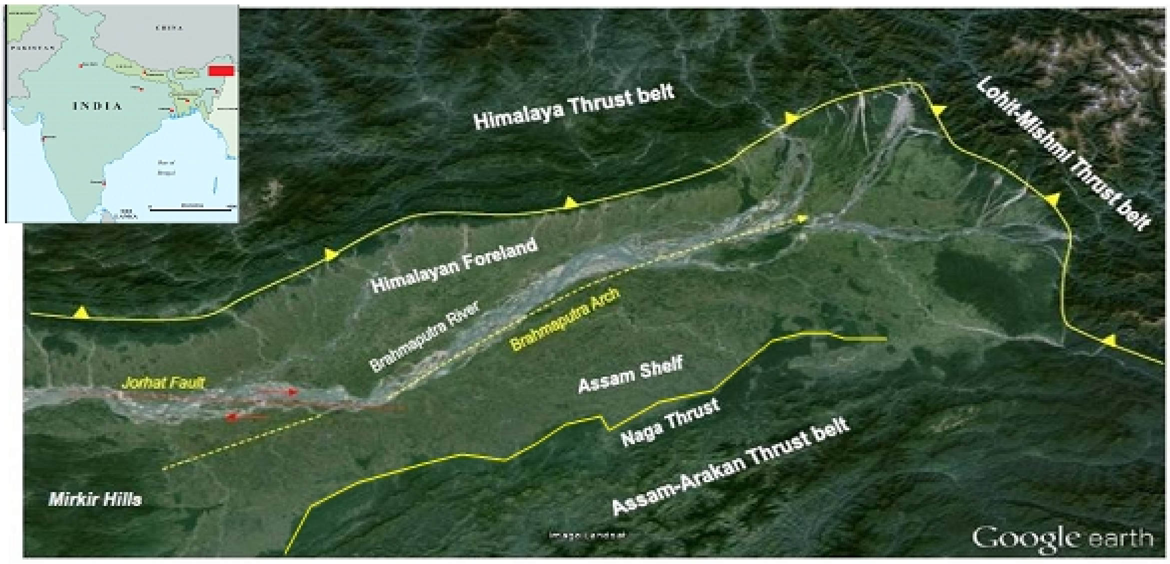


Figure 1: Location Map of Upper Assam Basin

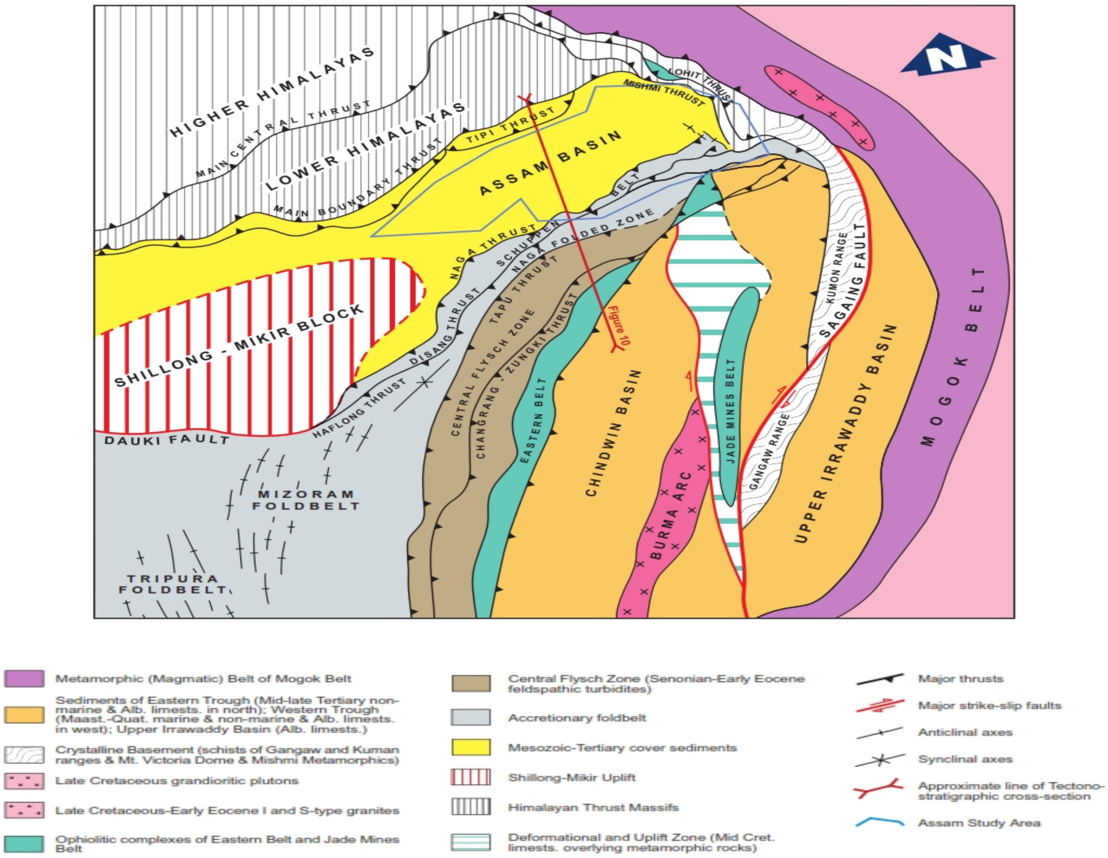


Figure 2: Tectonic Map of Upper Assam Basin

## Stratigraphy and Petroleum System:

Sedimentary sequence overlying Precambrian Basement is mainly subdivided into two parts viz. Palaeogene and Neogene separated by major Oligocene unconformity (Figure 3). The oil producing units in Paleocene-Eocene are the sandstones interbedded with organic rich carbonaceous shale, coal and a few carbonate units. These shales act as seal for Paleocene-Eocene reservoirs as well.

Late Eocene-Oligocene Barail Group comprising of mudstone, shale and coal of marginal marine to fluviatile environment acts as prolific source in deeper parts (in sub-thrust region) for oil generation. This source in turn feeds the relatively shallow reservoir sandstones. Coal shale sequences in Barail act as seal for reservoir in this formation. The Neogene sequence comprises Miocene and Mio-Pliocene reservoir rocks which were deposited in fluviatile environment. The Pliocene Girujan clay acts as a regional seal catering for hydrocarbon accumulation in Miocene Tipam reservoirs. Anticlines and faulted anticline structures, parallel to sub-parallel to north east trending Naga thrust are the primary traps. The region is characterized by NE-SW trending normal faults. Intersection of faults make separate fault blocks which act as traps for oil and gas accumulation (Figure 4).

Early Eocene shales and Paleocene-Early Eocene sands are likely to have formed the seal-reservoir doublets for long distance oil migration. The Barail arenaceous sands acted as a carrier bed for migration of oil generated in the Schuppen Belt. Vertical migration is implemented along the NE-SW trending faults and NW-SE trending cross-faults. Reactivation of faults and formation of anticlines resulted in lateral migration of oil from Naga thrust area since Pleistocene.

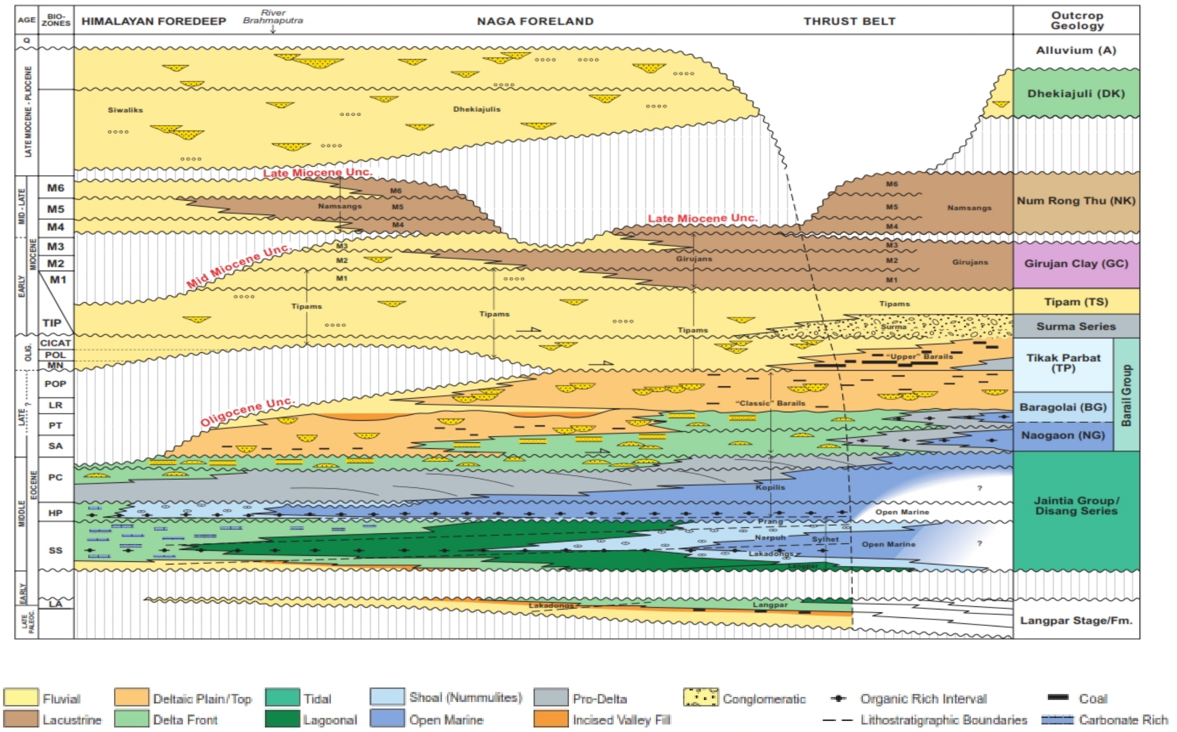


Figure 3: Generalized Stratigraphy of Upper Assam Basin

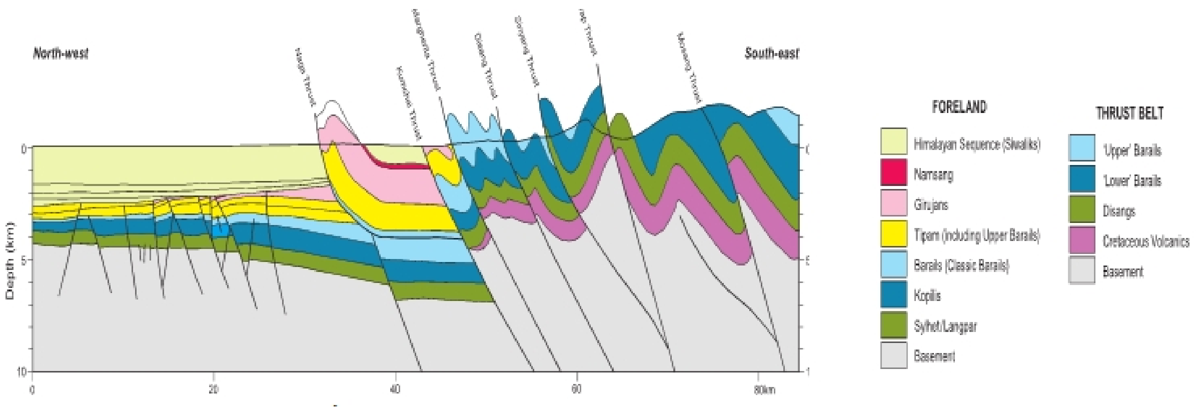


Figure 4: NW-SE Cross section showing faults and cross faults

## Methodology: Potential play identified as Area-1

A regional study was carried out with available seismic and well data to understand the structural configuration of the basin at different level. Structural maps and thickness maps along with available seismic and well sections were used to identify potential areas for exploration of deeper plays. The structural map on Paleocene-Eocene formation suggests that basin dips in southwestward and southeastward (Figure 5). Thickening of the Oligocene-Paleocene sequence in the Southeast and Southwest has also been observed (Figure 6). A play map on discovered and producing oil and gas structures in different formations has been prepared to understand the distribution of the plays in Upper Assam Basin (Figure 7). The play map indicates that the discovered Paleocene-Eocene reservoirs are concentrated mostly in the central part of the basin, south of Brahmaputra River. So far, exploration in southern part of the Upper Assam basin is limited to mostly shallower formation (Tipam-Barail). A regional NW-SE trending seismic section along profile-1 shows that the basin is dipping in south-east direction as well as Oligocene-Paleocene thickness is increasing in the south east (Figure 8). Well-A drilled in Balimara oilfield was drilled down to Kopili Formation and proved hydrocarbon bearing in Barail and Kopili Formation. A seismic profile through Well-A indicates presence of structural trap at Paleocene-Eocene level similar to that observed at Barail and Kopili level (Figure 9). Interpretation of well data indicates presence of reservoir rocks at depth more than 4700 m (Figure-12). Deeper Paleocene-Eocene in demarcated Area-1 would be interesting play for exploration.

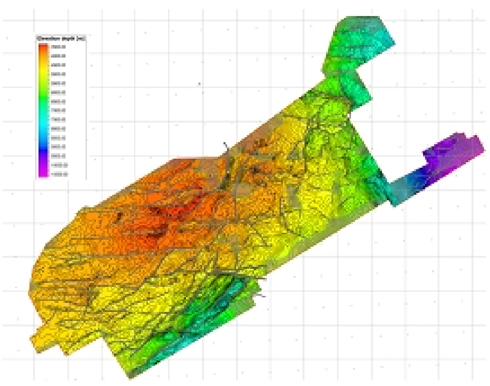

Figure 5: Structural Map on Langpar Formation

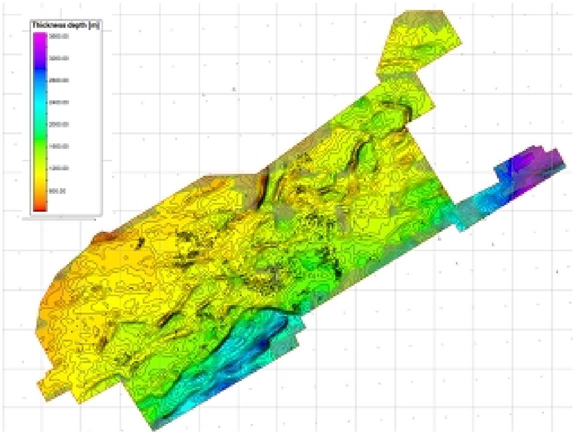

Figure 6: Barail-Langpar Isopach Map

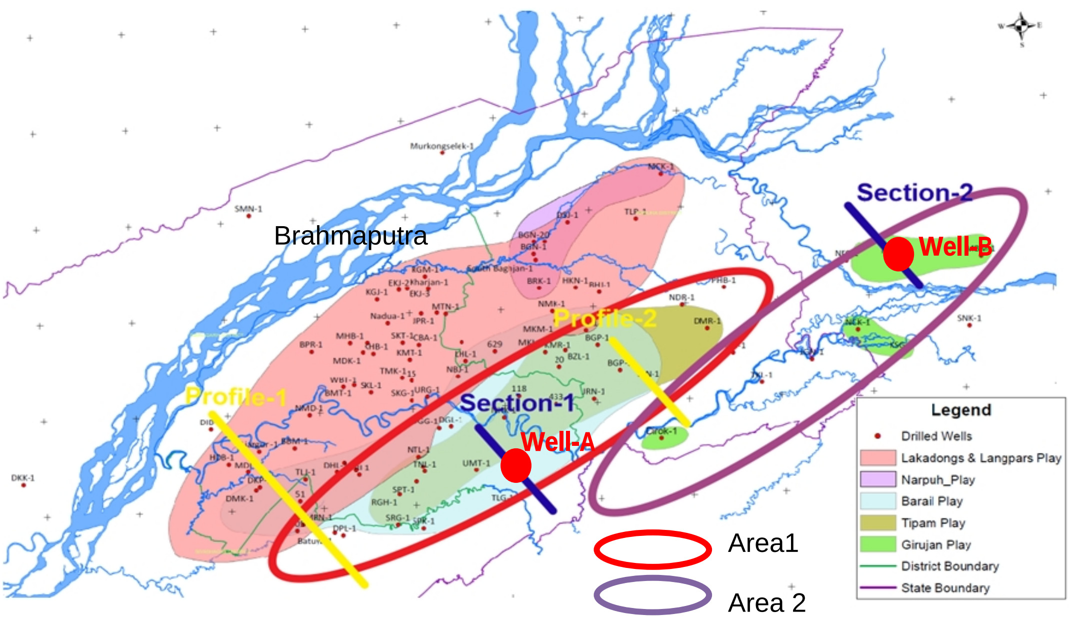

Figure 7: Play wise distribution of oil and gas fields in Upper Assam Basin

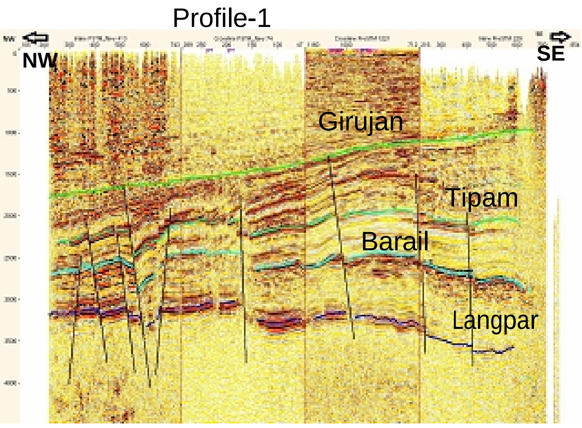


Figure 8: Regional Seismic Section

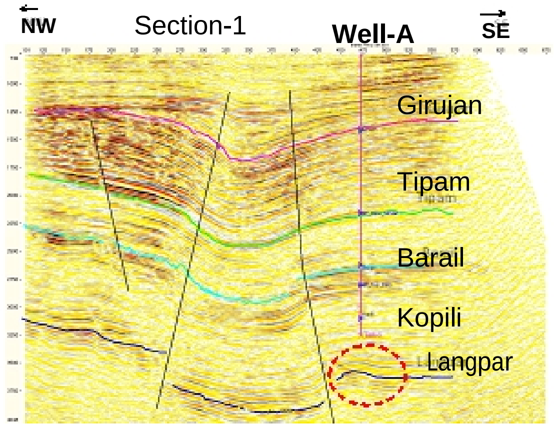


Figure 9: Seismic Section with deeper prospect

## Methodology: Potential play identified as Area-2

Several oil and gas fields have been discovered in hanging wall side close to frontal Naga Thrust region. The available seismic data shows the uncertainty of the sub-surface geometries in sub-thrust and supra-thrust areas. A seismic section along profile-2 shows poor imaging quality of the data in the sub thrust part below the Naga thrust (Figure 10). The section indicates the continuity of the seismic events in shelf part of the basin. However, seismic events are not clear below the frontal Naga thrust. Well-B drilled in supra-thrust Kumchai structure shows presence of hydrocarbon in Girujan Formation. The seismic profile through Well-B in section-2 shows structural trap at Miocene (Tipam) level also similar to that of Pliocene (Girujan) level (Figure 11). Interpretation of available well data indicates presence of reservoir rocks at depth more than 5000 m (Figure 12). Targeting deeper horizons in supra-thrust as well as sub-thrust in demarcated Area-2 would be an intesting play for exploration.

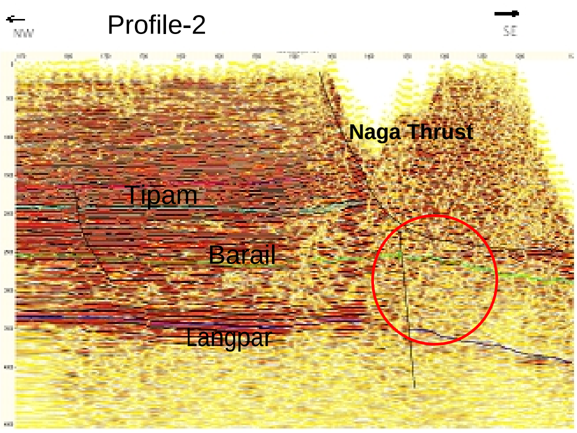


Figure 10: NW-SE Section showing seismic data Close to Naga thrust

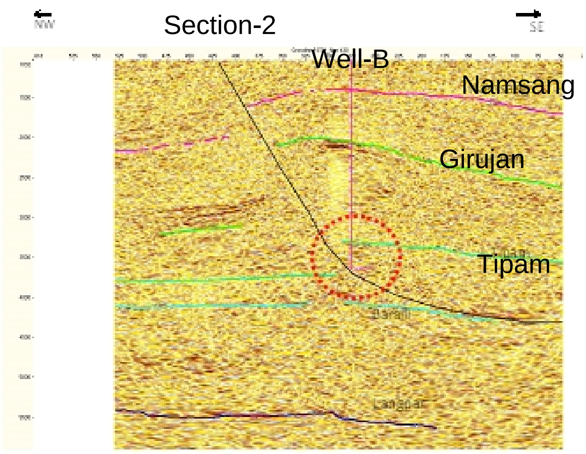


Figure 11: Seismic Section with deeper prospect

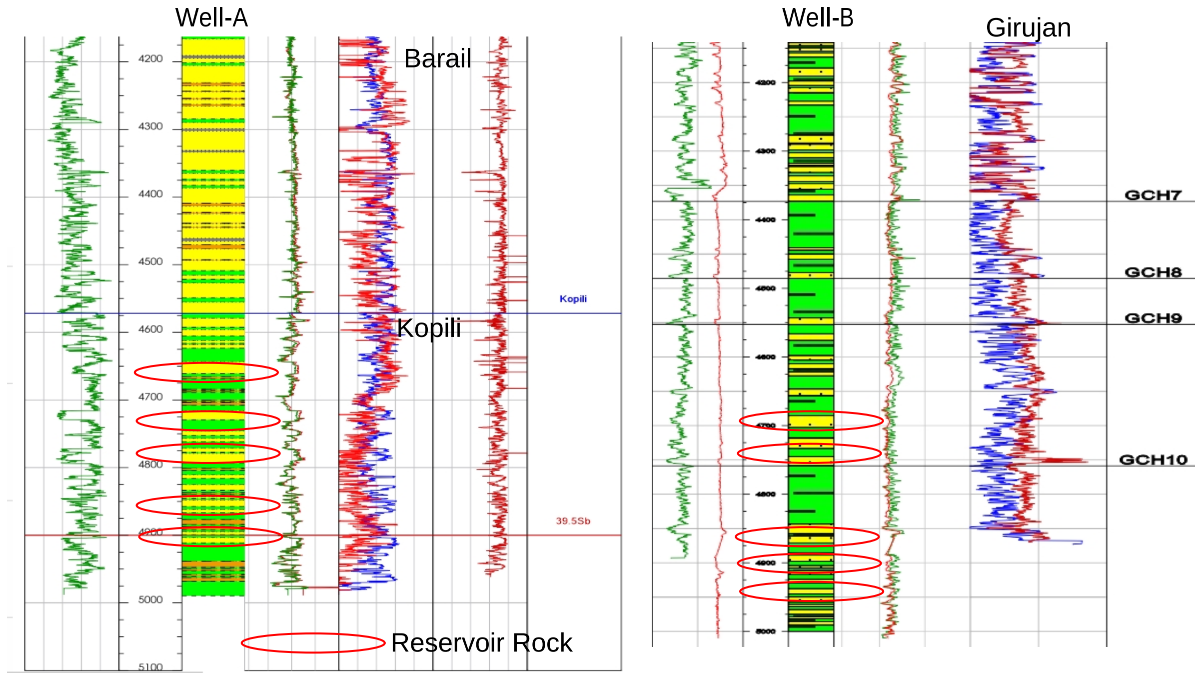

Figure 12: Well-A and Well-B shows presence of reservoir rocks at depth >4700 m

## Conclusion:

This study has been carried out to identify the potential play within the less explored area of OIL's acreages. Both seismic and well data has been used to demarcate two area of interest for future exploration. Area-1 has been demarcated for deeper Paleocene-Eocene play in the southern part of the basin whereas Area-2 has been identified in thrust region for relatively shallow plays at deeper level.

Exploration efforts of deeper Paleocene-Eocene plays have been limited to central part of the Upper Assam Basin. The play is less explored in southern part of the basin. The prospects for deeper Paleocene-Eocene plays needs to delineated and explored to establish commercial hydrocarbon at this level. However, greater depth and uncertain reservoir quality add further challenge for exploration and exploitation in this region. It may be noted that commercial hydrocarbon in the Paleocene-Eocene plays has already been established at depth more than 5600 m in Mechaki oilfield.

The exploration and exploitation in the frontal thrust and thrust belt area is limited to shallower Pliocene and Miocene plays. The deeper plays in this region are challenging frontier for oil and gas exploration due to complex or uncertain geometries. A robust geological model supported by advanced geophysical imaging is required to understand the complex sub-surface geometry of the sub-thrust and supra-thrust plays for exploration of deeper plays in thrust belt areas. An effort to exploit deeper plays will open a large area for exploration in the basin.

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